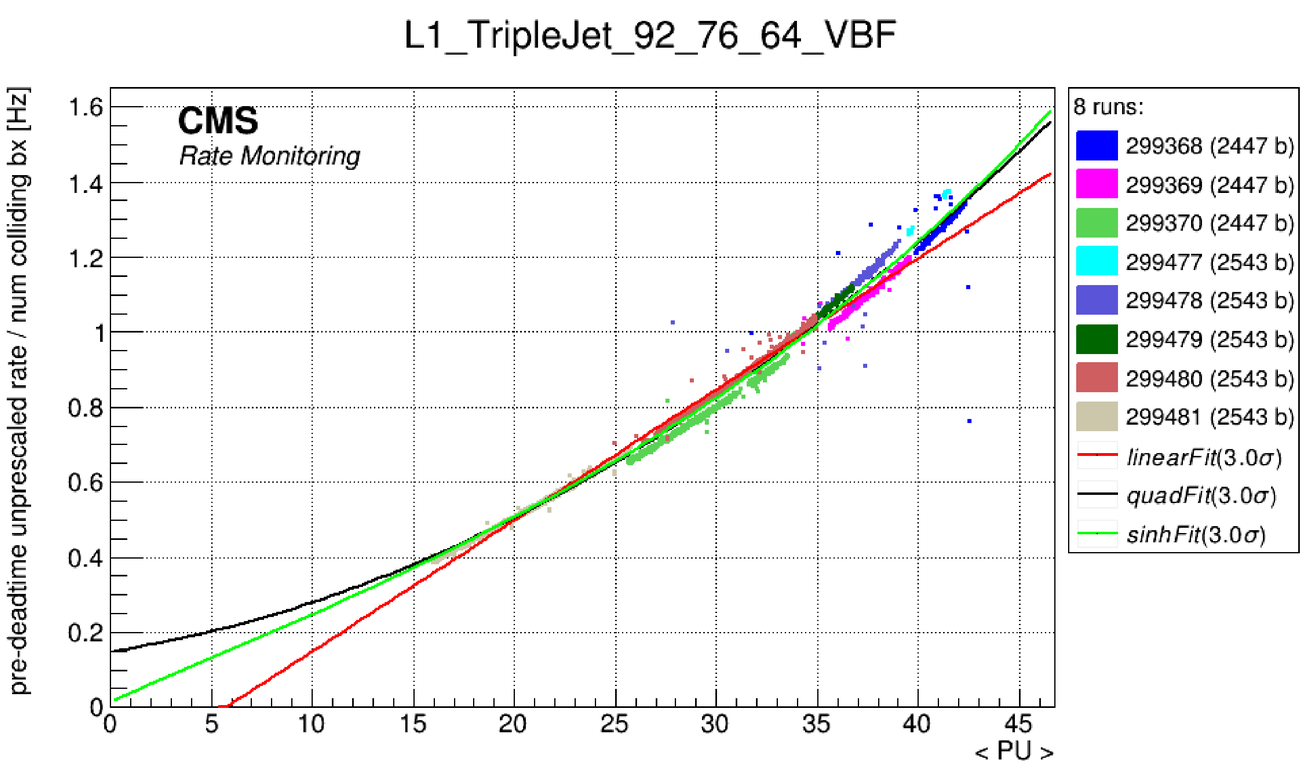
Tools for Trigger Rate Monitoring at CMS

Geoffrey N. Smith, Ph.D.
University of Notre Dame, South Bend, IN

Motivation

- The CMS trigger is extremely important. Roughly 500 separate algorithms combine to filter ≈40 MHz rate of collisions to ≈1 kHz of data. No trigger → no physics at CMS.
- As the LHC pushes to higher beam intensities, CMS has to be ready to respond to emergencies if the trigger rates go out of expected range.
- Trigger rate is very sensitive to all aspects of the detector and how they operate, so it often provides the first indication that something is wrong.
- Very important to be able to intelligently monitor, characterize and visualize trends in trigger rates.
- The trigger Field Operation Group at CMS has developed a sophisticated set of software tools to accomplish this task.
- Fits are made to the trigger rates in previous runs using linear and non-linear regression.
- These fits are then compared to the instantaneous trigger rate as data is being collected, in order to spot small (unexpected) deviations in rate.
- As well as this real-time component, the software provides a variety of additional features that are used in offline analysis.

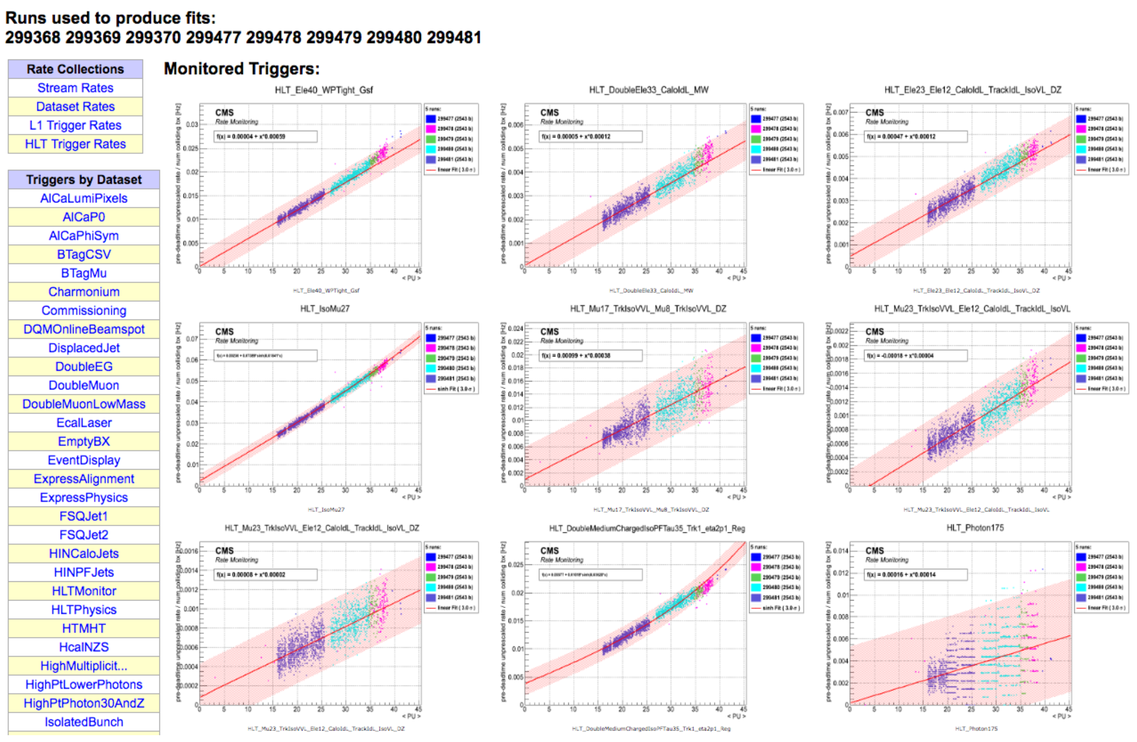
Fits



- First, fits are made to the trigger rate in previous runs as a function of average pile-up (<PU>)
- <PU>= average number of collisions in an LHC bunch crossing
- Runs to be fit are selected from a list of known good runs
- Before fitting, raw trigger rate is first corrected for deadtime, Level-1 (L1) and High Level Trigger (HLT) prescales, and number of colliding bunches in the LHC
- Corrected rate facilitates comparisons and extrapolations between runs with different conditions
- Allows smooth function to be fit between runs
- For each fit, several fit functions are attempted → final function selected based on χ^2 minimization

Web-Based Monitoring

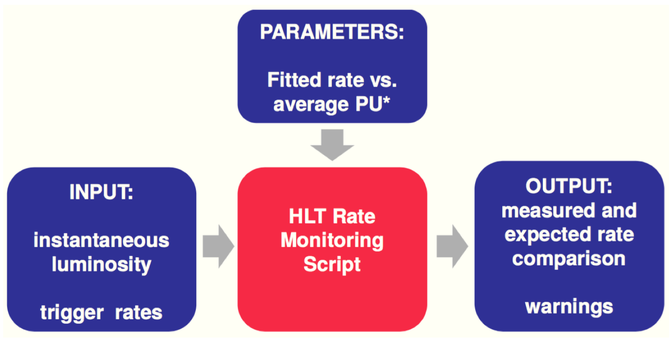
- Rate-vs-PU plots have been integrated into central CMS Web Based Monitoring service (WBM)
- Dedicated page linked from Fill Report page on WBM
- Cron job run every hour which updates the plots for the current fill
- Triggers in monitored trigger list shown on first page
- Plots for all HLT and L1 triggers, as well as stream and dataset plots available via links

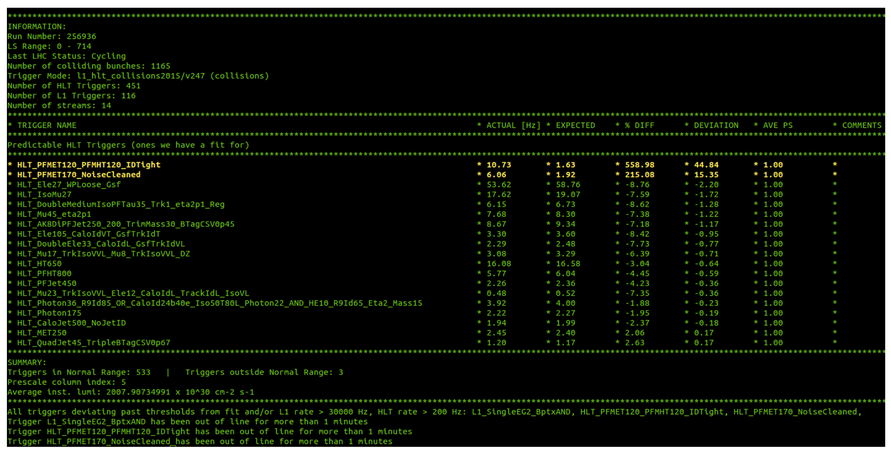


Above: Screenshot of rate vs. PU plots for fill 5976

Online Monitoring

- List of ≈20 L1 and HLT triggers is used for real-time online monitoring
- List is selected such that all CMS subdetectors are monitored and all physics objects are represented
- Automated script running 24/7 checks current trigger rates against prediction from fit for each trigger in list



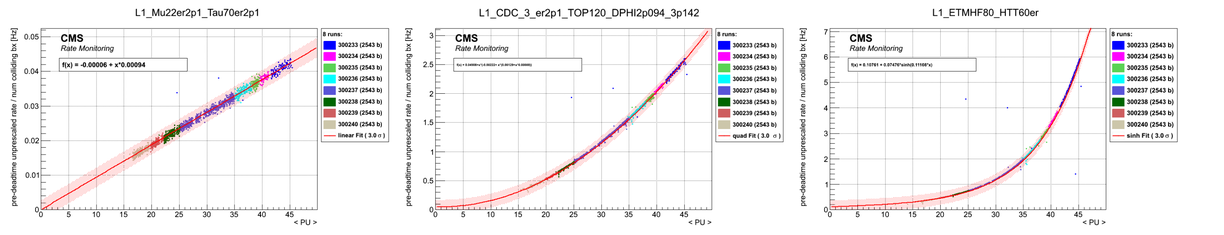


- Rates are queried from the database every 2 minutes
- Audible alarms and email warnings when trigger rate exceeds error band on fit for a significant period of time (currently 6 minutes)

Above: Screenshot of online trigger monitoring script. Here PFMET triggers are raising an alarm due to larger than expected rate, caused by a problem in HF.

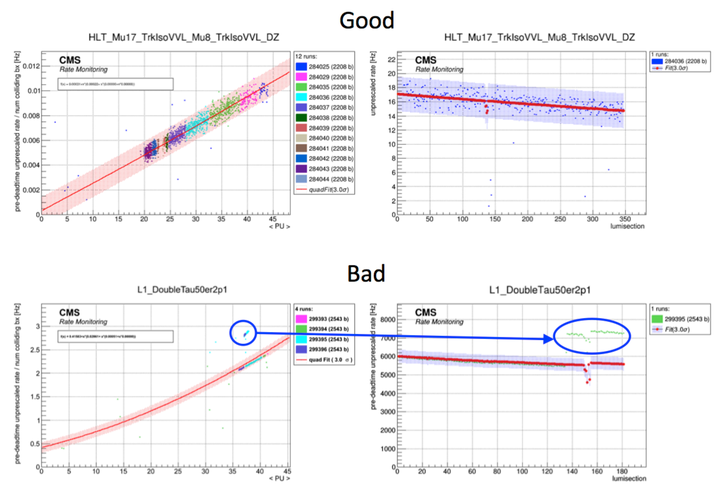
Fit Functions

- Ideally, trigger rates should depend linearly on beam intensity
- Due to background/experimental effects, some have nonlinear behavior
- After trying several options, we empirically found that the behavior of most triggers is well-described by either linear, quadratic, or exponential (sinh) functions



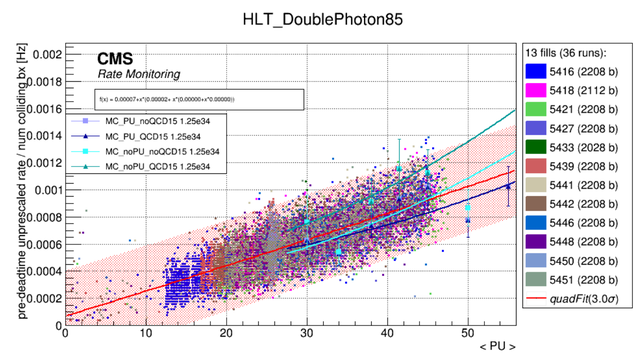
Run Certification

- Tool is also used for offline data certification
- For a given list of runs and list of triggers, rate vs. LS plots are produced for each run and trigger. Overlay of rate prediction from fit enables easy comparison by offline validators.
- Text summary is also produced highlighting the runs and LS where triggers deviated significantly from expectation
- Recent problems found by rate monitoring tool include:
  - Failed subdetector trigger hardware link
  - Beam spot mis-alignment
  - Luminometer calibration error



Offline Studies

- Code has a modular organization → can be extended to perform additional functions by other collaborators
- At right: plot from CMS Trigger Studies Group where rate-vs-PU information from real data (using our tool) is compared to several predictions from simulated data



More Info

- Other contributors to this software:
  - Andrew Wightman (U. Notre Dame): andrew.steven.wightman@cern.ch
  - Charles Mueller (U. Notre Dame): Charles.mueller@cern.ch
- Ratemon code on github: https://github.com/cms-tsg-fog/RateMon/
- Documentation: https://twiki.cern.ch/twiki/bin/view/CMS/RateMonitoringScriptWithReferenceComparison